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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Federal Communications Commission
MEMORANDUM

TO: William F. Caton, Acting Secretary

FROM: L. Charles Keller, Attorney-Advisor, Universal Service Branch, Accounting & Audits Division, Common Carrier Bureau

DATE: August 20, 1997

RE: Notice of Ex Parte Communication
CC Docket No. 96-45 (Federal -State Joint Board on Universal Service)
CC Docket No. 97-160 (Forward-Looking Mechanism for High-Cost Support for Non-Rural LECs)

This morning, Professor David Gabel of Queens College of the University of the City of New York met with various members of the Commission staff to present his views on methods and data for estimating switching and cable costs in a forward-looking cost mechanism. The information he presented will be published by the National Regulatory Research Institute in a forthcoming article, "Estimating the Cost of Switching and Cables Based on Publicly Available Data."

Attached is a draft copy of the article, which lays out the positions and findings that Prof. Gabel presented to us this morning. Also attached is a copy of the overhead slides he used in his presentation, along with a hand-out describing the methodology he used in his study. These materials fully summarize the information that Prof. Gabel presented.

The following FCC staff members were present: Brad Wimmer, CCB; Bill Sharkey, CCB; C. Anthony Bush, OGC; D. Mark Kennet, CCB; Bryan Clopton, CCB; Emily Hoffnar, CCB; Natalie Wales, CCB; and myself.

Various members of the telecommunications industry, representing the proponents of the cost proxy models that are under consideration in the above-referenced proceedings, also were present, but did not make substantive presentations to the Commission. The following individuals were physically present; other representatives of the model proponents also monitored the presentation by telephone: Glenn Brown, US West; John Donovan, AT&T/MCI; Mark Bryant, MCI; Chris Frentrup, MCI; Brian Staihr, Sprint; Warren Hannah, Sprint; Bob Mercer, Hatfield Assoc.; and Mike Lieberman, AT&T.

Gary Allen and Ed Cameron of the Rural Utilities Service, U.S. Dept. of Agriculture, were present for the presentation, and provided background information on the scope and limits of the data relied upon by Prof. Gabel. Also listening to the presentation by telephone were David Dowds of the Florida Public Service Commission and Ann Dean of the Maryland Public Service Commission.

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Estimating the Cost of Switching and Cables Based on Publicly Available Data

Switch Acquisitions of Small Telephone Companies

The sponsors of the proxy models have provided estimates of the cost of ital switches used by large local exchange companies. The purpose of this section of the report is to provide an estimate of the payments made by small telephone companies.

Many small telephone companies receive financing assistance from the Rural Utility Service (RUS). RUS, which is a federal agency within the Department of Agriculture, requires telephone companies to file with the agency the payments made for new switches. I have obtained from the RUS data on the cost of digital switches acquired in the past three years. The data is found in the excel worksheet **rus central office data.xls.**

The file contains the purchase price for 136 switching machines. These equipment prices exclude the cost of the local exchange companies engineering costs. Based on my conversations with personnel at RUS, I recommend that a loading of 10% be added to the costs to reflect telephone company engineering by small companies. The prices do reflect the vendor's cost of installing the equipment.

The excel spreadsheet also indicates the number of equipped lines. For eleven of the observations, there are no equipped lines. For these offices, the reported investment levels are the additional costs incurred at the host when it terminates the umbilical DS1 links between the host and the remote. Whereas the purpose of this analysis is to identify the total switch investment, the incremental host investments have been excluded from the data set used for regression analysis.

I have not included in the data set information on the cost of upgrades to existing switches. For example, periodically, LECs purchase new software or processors. While information on these upgrades are available from the RUS, I have not included such information in the data set because the focus of the USF and UNE modeling has, arguably, been the cost of installing new switches.[1] Furthermore, when upgrades take place, the contracts typically only cover a portion of the cost of a switch. Since the total cost of the switch would not be included in the contract, the data on the cost of upgrades is of only limited value for the studies currently being conducted.

The cost of terminating the remote on the host switch should be included in the proxy models. The following Table indicates that the incremental investment associated with terminating a remote on a host switch.[2] The cost varies due to the lumpy nature of the equipment. The DS1 connections between the host and remote are terminated on modules that can handle a discrete number of DS1 links.[3] For example, a Nortel digital trunk module may terminate up to 20 DS1 links. The getting started cost of the module provides capacity for up to 20 DS1 links. If a new remote is terminated on the host, the effective cost of terminating the remote on the host depends on the extent to which a new module must be acquired. If there is sufficient capacity on the existing modules, the incremental cost will be low. If on the other hand, a new module must be acquired, the effective cost is much higher.

[1]Considering the cost of a new switch is consistent with the approach taken when modeling the cost of the loop. When modeling the cost of the loop, parties have estimated the cost of constructing an all new loop network. The cost estimates for the loop have not been based on a mix of new installations and expanding the capacity of existing facilities.

[2]The incremental investment was calculated by dividing the investment associated with the terminations on the remotes by the number of in-service remote switches supported by the investment.

[3]The number of DS1 links between the host and remote is largely a function of the amount of busy-hour CCS traffic.

Table 1 Incremental Investment associated with Terminating a Remote on a Host Switching Machine	
Mean	27,598.29
Standard Deviation	26,455.61
Minimum	4,298.4
Maximum	98,655
Number of Host Switching Machines	11

This table indicates that the average cost of terminating a host on a switch is $27,598.29.[4] The incremental cost of these links are not included in the regression results reported below.

Many of the remotes included in the data set are line frame units that have varying numbers of line cards. These line units are dependent on the host for originating and terminating calls. Nevertheless, these remote line units can operate on a stand-alone basis. For example, Siemens Stromberg-Carlson provides the following description of the capabilities of its remote line switches that terminate 360, 450, or 1,000 lines:

> "When communications with the host office are lost, the RLS [remote line switch] enters the ESS [emergency switching system] mode (if provided). The intranodal switch option is a prerequisite for the ESS feature. While in optional ESS mode, all call processing functions required for line-to-line calls within the RLS are performed by the RLS instead of by the host office. Host office operations assumed by the RLS include the following:
>
> Provides call progress tones (dial tone, ringback tone, busy tone, etc.).
> Collects either DTMF or rotary-dial pulses.
> Provides call routing for off-hook service and after one, three, or seven digits have been dialed.
> Provides features and enforces restrictions defined by the line class of service.
> Records number of call originations and terminations
> Recognizes call release.

[4]This value excludes the ten percent Telco engineering cost.

Provides coin control for paystation lines.

Provides multiline hunting.

Two 5-line hunt groups can be provided for emergency outgoing service. These connections are separate from the normal RLS-to-host links. Lines in these groups can be reached by dialing 1-,3-, or 7-digit numbers defined by the operating company."[5]

Descriptive Statistics for RUS Data Set

The following Table shows the distribution of lines on the RUS host and remote switches that are included in the data set.

Table 1
Descriptive Statistics: RUS Switches

Percent Distribution	Line Size on Remote Switching Machines	Line Size on Host Switching Machines
1%	36	350
5%	73	350
10%	109	412
25%	200.5	500
50%	301.5	937
75%	779	1920
90%	1342	2561
95%	1664	17020
99%	2480	17020
Mean	579	2339
Std. Dev.	624	4479
Observations	112	13

[5] ***Remote Line Equipment: Remote Line Switches 360, 450, and 1000***, Siemens Stromberg-Carlson Publication No. 00-300-04, Issue 8, December 1994, p. 12-13.

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Model Specification

In the regressions below, I use the following functional form to estimate how the investment per switch varies as the number of equipped lines increases:

investment per switch = A + B * lines + ϵ

Where:

A = The fixed cost of a switch

B = The investment per equipped line

ϵ = random error

The data points have been classified as either host or remote switches. The classification is based on information contained in the RUS contracts. The distribution of lines on these two types of switches are shown on Table 1.

The actual specification of the model is a little more completed than suggested by the above equation. In recognition that the getting started cost of a host switch is greater than the value for a host. I have included a dummy variable for the host switches. I also allow for the investment per equipped line to be different on a host and remote switch. By taking into account that the investments for a remote and host switch differ, I have used the following functional form:

investment per switch = β_1 +β_2 * host_indicator + β_3 *remote_lines + β_4 * host_lines + ϵ

Where:

β_1 = The fixed investment for a remote switch = _cons

β_2 = The incremental fixed investment for a host switch = host

β_3 = The incremental investment per line termination on a remote switch = remoline

β_4 = The incremental investment per line termination on a host switch = hostline

ϵ = random error

Note that β_2 is the incremental fixed investment for a host switch. The total fixed investment for a host switch is β_1 + β_2.

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Regression Results

The following parameter estimates were obtained from the data set:

Source	SS	df	MS		
				Number of obs	= 125
				F(3, 121)	= 141.17
Model	4.8815e+12	3	1.6272e+12	Prob > F	= 0.0000
Residual	1.3947e+12	121	1.1526e+10	R-squared	= 0.7778
				Adj R-squared	= [illegible]
Total	6.2762e+12	124	5.0614e+10	Root MSE	= 1.1e+05

total	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
host	534992.8	36616.79	14.611	0.000	462500.2	607485.4
remoline	144.5748	16.32458	8.856	0.000	112.256	176.8936
hostline	42.6869	6.918898	6.170	0.000	28.98912	56.38468
_cons	54269.76	13862.45	3.915	0.000	26825.38	81714.13

Returning to the equation above, the parameter estimates suggest that the

investment per switch = $\beta_1 + \beta_2$ * host_indicator + β_3 *remote_lines + β_4 * host_lines

= 54,269.76 + 534,992.8 * host_indicator + 144.58*remote_lines + 42.69 * host_lines

These results can be used as follows within the proxy models (assuming that the ten percent engineering loading factor is taken into account elsewhere in the proxy models):[6]

Investment per host switch = 54,269.76 + 534,992.8 * host_indicator + 42.69 * host_lines

= 589,262.6 + 42.69 * host_lines

Investment per remote switch = 54,269.76 + 144.58*remote_lines

The RUS companies buy switches either through a competitive bidding or a negotiated

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[6]The data set indicates the number of equipped lines, rather than the number of working lines. Therefore the incremental investment per line termination, \$42.69 and \$144.58, are the estimates for an additional line of capacity. Digital switches do not operate at full capacity. Consequently, where these parameter estimates are used to estimate the cost of providing universal service or unbundled network elements, the values must be divided by the line switch utilization. There is no need to adjust the fixed cost of the switches for utilization since, by definition, the fixed cost is independent of the level of utilization.

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contract process. If the telephone company is already using a particular type of digital switch, it may decide that it has no choice but to buy the new switch from the same vendor. For example, if the sub-tending host switching machine is manufactured by Lucent technologies, the RUS company must also install a Lucent switch at the remote office. In those situations where the local exchange company is able to buy a switch from any vendor, the RUS regulations require the telephone company to issue a request for proposals. The bid selected through the RFP process is referred to as a competitive bid contract.

The data set indicates if the switch was purchased as a result of competitive bidding or is a negotiated price. The following table indicates the cost for the host and remotes when the supplier is selected through a competitive bidding process:

Source	SS	df	MS
Model	1.9788e+12	3	6.5960e+11
Residual	1.5549e+11	40	3.8872e+09
Total	2.1343e+12	43	4.9635e+10

Number of obs =	44
F(3, 40) =	169.69
Prob > F =	0.0000
R-squared =	0.9271
Adj R-squared =	0.9217
Root MSE =	62347

total	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
host	538210.6	46106.44	11.673	0.000	445026	631395.2
remoline	87.36579	22.84098	3.825	0.000	41.20245	133.5291
hostline	57.58742	27.8185	2.070	0.045	1.364144	113.8107
_cons	42504.89	15552.48	2.733	0.009	11072.17	73937.62

The parameter estimates suggest that the competitive bid price for a remote switching machine was 42,504.89 + 87.37*remote_lines. For a host switch, the regression analysis suggests that the cost function was (42504.89. + 538210.6) + 57.59 * host_lines = 580,715.5 + 57.59 * host_lines.[7]

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[7]This specification of the investment function exhibits heteroscedasticity. There are a few ways in which this can be addressed. First, a common technique is to take the logarithmic values of the right and left-hand side variables. When I did this, the heteroscedasticity was corrected, but the goodness of fit declined. Since the goal is to explain the total level of investment, and whereas the linear model explains more of the variation in the dependent variable, I have reported the results from the linear model. The results from the logarithmic estimates are reported in file **rus switching log**.

Alternatively, a statistical program can be used to correct for the heteroscedasticity. I have

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The following table indicates the cost for the host and remotes when the price is established through negotiations:

Source	SS	df	MS		
				Number of obs =	81
				F(3, 77) =	69.07
Model	3.0045e+12	3	1.0015e+12	Prob > F =	0.0000
Residual	1.1165e+12	77	1.4500e+10	R-squared =	0.7291
				Adj R-squared =	0.7185
Total	4.1211e+12	80	5.1513e+10	Root MSE =	1.2e+05

total	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
host	505106.3	59914.68	8.430	0.000	385800.9	624411.7
remoline	152.312	20.19457	7.542	0.000	112.0995	192.5246
hostline	43.12614	8.124278	5.308	0.000	26.94863	59.30364
_cons	69794.98	18597.88	3.753	0.000	32761.87	106828.1

The parameter estimates suggest that the negotiated bid price for a remote switching machine was 69,794.98 + 152.31*remote_lines. For a host switch, the regression analysis suggests that the cost function was (69,794.98 + 505,106.3) + 43.13 * host_lines = 574,901.3 + 43.13 * host_lines.

Discussion of Regression Results

I have used the data set to estimate the price of new switching installations. For this group

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used the Stata option rreg to obtain robust estimates of the parameters. With this option, outliers are deleted and then the program obtains robut confidence standard errors. The results from using this technique are reported below:

Robust regression estimates

Number of obs =	42
F(3, 38) =	2168.67
Prob > F =	0.0000

total	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
host	386152.9	11010.45	35.071	0.000	363863.4	408442.4
remoline	79.95052	4.594921	17.400	0.000	70.64858	89.25245
hostline	95.41726	7.186679	13.277	0.000	80.86858	109.9659
_cons	39160.86	3128.693	12.517	0.000	32827.15	45494.57

Note that the number of observations is smaller than in the results reported above. This is because the robust routine in Stata discards outliers.

of purchases, I have provided parameter estimates using data on either all, competitive or negotiated acquisitions. Regardless of which estimates are used within the proxy models, the data set provides a good indication of what is the cost of a host switching machine. In three of the regression runs, the fixed and per line investment for the host switch was approximately $580,000 and $50 respectively. If two outliers are discarded, the fixed and line investments are approximately $425,313.8 and $95.42 respectively.

For the remote switching machines, the fixed investment is in the neighborhood of $50,000. This cost represents the getting started cost for a small remote switching machine. It does not represent the getting started cost for a large remote switching machine. The per line investment exhibits a great deal of variance. There is a great deal of difference in the investment per line depending on if the price is negotiated ($152) or established through a competitive bidding process ($87). The $87 value is lower in part because the price is established through a competitive bidding process.[8]

These parameter estimates may be used by Commissions for estimating the cost of unbundled network elements or for establishing the cost of providing universal service. The strength of the data is that many of these prices were established through a competitive bidding process and the prices are in the public domain.

Unfortunately the contracts do not indicate the level of traffic that will be handled by these switches. Busy-hour calling volume and holding times have a significant impact on the design of switching machines. Since usage is positively correlated with the number of the lines, the cost impact of usage is effectively included in the per line investment estimates. Both of the proxy models arbitrarily split the per line investment between usage and the port cost. As discussed in the monograph "Improving Cost Proxy Models," the appropriate split depends largely on the treatment of the central processor.[9]

Arguably the investment estimates provided above should be interpreted as being greater

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[8]Other factors could be contributing to the lower price in competitive situations. For example, usage could be lower on the switches acquired through the competitive process.

[9]David Gabel, *Improving Cost Proxy Models for Use in Funding Universal Service*, NRRI 96-34, pp. 31-33.

than the prices paid by large local exchange companies. The larger local exchange companies have greater buying power than the RUS companies and therefore likely obtain equipment at a lower price. The magnitude of the differential between the price paid by large and small companies is not clear; I am aware of any publicly available data that indicates the magnitude of the discount provided to one group of companies versus the other.

On the other hand, the capacity of the switches used by the large LECs is typically greater than for the switches purchased by small LECs. But the capacity of the switches used by the Independent Telephone companies should not be inferred from the data provided above. Table — indicates that the largest host and remote included in the RUS data base was 2,480 and 17,020 remote and line terminations respectively.[10] Some of the RUS companies deploy the DCO switch. The DCO system can serve up to 32,400 lines in an end-office configuration.[11] The DCO system can serve up to 70,000 lines as a network host. The DCO switch can be connected to various types of remote switches. The largest of the remotes, the RLS-4000, can support up to 4,500 lines.

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[10]The data set is not exclusively switches with comparatively small capacity. For example, the data set includes information on the Lucent #5ESS switching machine.

[11]An end office configuration would mean that the entire customer base interfaces with the DCO system via direct wire connections.

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Switching Investments: Large Companies

Data Sources

The data for this regression analysis was obtained from the Federal Communications Commission. The data files, which are included on the attached disk provided with this report, include the following information for each switch: the location of the office in which the switch is installed; the model designation of the switch; the year the switch was first installed; the lines of capacity; the installed cost of the switch; and the switch's cost per line. In a Public Notice, the Commission provided the following description of the data:[12]

> Large incumbent LECs file depreciation rate reports with the Commission pursuant to 47 C.F.R. section 43.43. Prior to filing these reports, companies generally submit depreciation rate studies that include data for each digital switch in operation. The switches in this data set consist of all of the RHCs' digital switches that were reported as installed between 1983 and 1995 in the states specified, with certain exceptions. To increase the reliability of analyses using these data, the following switches were removed from the data set: (1) switches for which there were no lines of capacity, such as those functioning solely as tandem switches; (2) switches with fewer than 1000 lines of capacity; and (3) switches that were deemed to be "outliers" because of unusually high or low per-line costs.[13] The data set contains at least one state from the area served by each RHC.

I have made some modifications to the data set that are documented on the disk that

[12] Spreadsheet of Digital Switching Data from Depreciation Rate Studies Available, CC Dockets Nos. 96-45 and 97-160, Released: August 4, 1997, DA 97-1663.

[13] The following procedures were used to identify outliers: (1) if there was a gap of 20% or more between the per-line cost of a switch and the next lower, or higher, cost switch, the switch and any others with lower, or higher, per-line cost were excluded; (2) a low-priced switch that failed test 1 was nevertheless retained in the data set if a lower per-line switch cost would have passed test 1 in a previous year; (3) a high-priced switch that failed test 1 was retained in the data set if a higher per-line switch cost would have passed test 1 in a subsequent year. These rules removed about 40 outliers from a data set containing per-line cost data for nearly 3600 switches. In addition, a small number of switches associated with apparent inconsistencies in the studies were not included in the set. In particular, for several locations in California, switches at the same location of different capacities, types, and years of installation were reported as having the same per-line costs. These anomalies were judged to be the results of averaging by the respondent and the switches in these locations were excluded from the data set.

accompanies this report.[14] Some of the data classifications did not seem reasonable and therefore I reclassified the type of switch. For example, the data set identified as DMS-100® or 5ESS® switches certain wire centers that terminated less than 2,000 customers and cost in the neighborhood of $500,000. Based on my past review of cost data, it seemed more reasonable to assume that these locations were remote switching machines.

I have converted the embedded costs to 1997 values by using the Turner Price Indexes. The indexes are available by region of the country, but for digital switching there is no variation between areas.

The local exchange companies regularly use telephone plant indexes to convert embedded to current cost data. For example, many companies use this methodology to construct maintenance annual charge factors. The maintenance annual charge factors are typically expressed as the ratio of current maintenance costs divided by current investment. The denominator, the current investment, is estimated by multiplying the yearly net investments by telephone plant indexes.

The accounting records identify the book investment for each switch. In less densely populated regions, remote switching machines are used to terminate customer lines. The remote switching machines are quite dependent on a host switching machine for interoffice traffic, and for setting up and taking down all calls. Part of the cost of the host switching machine therefore should be attributed to customers on the remote switching machine. Whereas the data in the depreciation reports do not permit us to identify the investment on the host switching machine that is attributable to customers on the remote, the econometric cost estimates understate the cost of a serving a rural customer.

I do not believe that this understatement causes a large distortion. The incremental cost of handling remote traffic on a host switching machine is often not large. There are costs associated with terminating the trunks, processing the calls, and using the network on the host switch. In terms of total dollars, these are not large costs.

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[14]See file: new log with corrected data.

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I have only used data from years 1985 forward.[15] Prior to the divestiture of AT&T, the Bell Operating Companies purchased almost all of their equipment from their sister company, Western Electric. This arrangement impeded the development of competitive pricing in the switching market, and therefore I have excluded pre-divestiture data. I also excluded data from 1984 on the grounds that it was a transitional year and therefore the market prices were not reflective of the competitive conditions that emerged in later years.

For the years 1985 through 1995, there are 3,394 observations in the data base. 2,848, or 84% of these observations are either DMS-100®, DMS-100® remotes, #5ESS®,#5ESS® remotes, or EWSD switching machines. I have limited my analysis to these machines because it is not clear for the other observations the extent to which the observations are host or remote switching machines. Furthermore, by limiting the analysis to a few family of products, it possible to obtain more precise parameter estimates.

[15]Limiting the scope of years to the post 1984 era is consistent with the approach taken by the FCC Staff in their own analysis of the data. The Staff's Analysis is discussed in the *Further Notice of Proposed Rulemaking*, CC Docket No. 96-45, July 18, 1997, Par. 130.

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Descriptive Statistics: RBOC Switches Used In Regressions		
	Remotes	Hosts
1%	1,024	3,584
5%	1,208	6,400
10%	1,280	8,960
25%	1,920	13,162
50%	3,072	21,856
75%	5,147	36,928
90%	7,616	55,422
95%	9,243	67,429
99%	13,376	98,490
Mean	3,958	27,845
Std. Dev.	3,397	20,716
Observations	1,409	1,439

The number of lines terminated on the RBOC switches is considerably greater than for the RUS companies.[16] Many of the large LEC's host switches are located in urban areas and therefore it makes economic sense to terminate a large number of lines on these switches. Somewhat surprisingly, there is also a large difference in the number of lines terminated on a remote switch. Some of this difference is attributable to the way in which the RBOC data set was created. The data set excludes data of switches in which there are less than 1,000 lines. Hence the average number of lines reported on the table above is greater than the population mean value.

[16]The statistics provided in this Table are based on the data used in the cost estimates. My data sets do not include the entire population of switches.

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As stated above, the data set excludes switches with fewer than 1,000 lines of capacity. As a matter of sound econometrics, caution must be exercised when parameter estimates from a data set are used to forecast into regions for which there are no observations. To the extent to which the offices with less than 1,000 lines are or would be using the same type of switches as those with more than 1,000 lines, I feel comfortable using the parameter estimates from the regressions. To the extent to which wire centers with less than 1,000 lines are using different types of switches, the parameter estimates reported in this chapter should not be used. A reasonable alternative would be the parameter estimates reported in Chapter — for the Rural Utility Service Companies.

Regression Model

In this paper, I have used the standard specification of the cost function to estimate the investment function for switching machines:

investment per switch = A + B * lines + ϵ

Where:

A = The fixed cost of a switch

B = The investment per equipped line

ϵ = random error

This equation simply states that there is a getting started cost for a switch, the coefficient A, and an investment per additional line terminated on the switch, B.

The actual specification of the model is a little more completed than suggested by the above equation. In recognition that the getting started cost of a host switch is greater than the value for a host, I have included a dummy variable for the host switches (5ESS®, EWSD, DMS-100®, and DMS-10®). I also allow for the investment per equipped line to be different on a host and remote switch. By taking into account that the investments for a remote and host switch differ, I have used the following functional form:

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investment per switch = β_1 +β_2 * host_indicator + β_3 *remote_lines + β_4 * host_lines + ϵ

Where:

β_1 = The fixed investment for a remote switch = _cons

β_2 = The incremental fixed investment for a host switch = hostdm10

β_3 = The incremental investment per line termination on a remote switch = relinexp

β_4 = The incremental investment per line termination on a host switch = hsdm10li

ϵ = random error

Note that β_2 is the incremental fixed investment for a host switch. The total fixed investment for a host switch is $\beta_1 + \beta_2$.

Regression Results

The following parameter estimates were obtained from the data set:

```
Regression with robust standard errors               Number of obs =     3023
                                                     F(  3,  3019) =  2520.84
                                                     Prob > F      =   0.0000
                                                     R-squared     =   0.7994
                                                     Root MSE      =  1.1e+06
```

cost1997	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
hostdm10	746170.7	69455.02	10.743	0.000	609986.8	882354.6
hsdm10li	107.2468	3.326741	32.238	0.000	100.7239	113.7697
relinexp	94.47673	6.513561	14.505	0.000	81.70527	107.2482
_cons	199412.8	24131.39	8.264	0.000	152097.2	246728.4

Returning to the equation above, the parameter estimates suggest that the investment per switch = β_1 +β_2 * host_indicator + β_3 *remote_lines + β_4 * host_lines

= 199,412.8 + 746,170.7 * host_indicator + 94.48*remote_lines + 107.25 * host_lines

These results can be used as follows within the proxy models:

Investment per host switch = 199,412.8 + 746,170.7 * host_indicator + 107.25 * host_lines

= 945,583.5 + 107.25 * host_lines

Investment per remote switch = 199,412.8 + 94.48*remote_lines

The data set indicates the number of equipped lines, rather than the number of working lines. Therefore the incremental investment per line termination. $94.48 and $107.25. are the estimates for an additional line of capacity. Digital switches do not operate at full capacity. Consequently, where these parameter estimates are used to estimate the cost of providing universal service or unbundled network elements, the values must be divided by the line switch utilization. Line switch utilization typically runs in the range of 90 to 95%.[17]

The parameter estimates should not be used to estimate the cost of terminating an ISDN line on a switch. During the years covered by this data set, the overwhelmingly majority of the lines were for voice service.[18] Therefore the investment line estimates do not reflect the additional costs associated with providing ISDN lines on a digital switching machine.

These parameter estimates suggest that contrary to the claims of the sponsors of BCPM 1.1 and Hatfield 3.1, the fixed cost of a host and remote switch differ significantly. Furthermore, the point estimates for the incremental investment for terminating a line on a remote and host switch differ. The difference in the line termination investment estimates may be due to the higher per line traffic on host switching machines. Host switching machines, relative to remotes, are more likely to be located in urban areas. Urban areas have higher busy-hour traffic usage[19] and due to the high correlation between the number of lines and total busy-hour usage, the traffic-sensitive cost is likely being picked-up by β_3 and β_4.

Alternative Estimation of the Investment Function

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[17]The level of utilization on a digital switch is higher than in the loop because of the modularity of the plant. For example, in the Nortel family of products, the DMS-10® and DMS-100® switching machines, one line card is dedicated to each customer.

[18]Federal Communications Commission, Statistics of Communications Common Carriers, 1994/1995 Edition, U.S. Government Printing Office (1995), Tables 2.4, 2.5, and 2.6.

[19]See, for example, Bridger M. Mitchell, *Incremental Costs of Telephone Access and Local Use*, RAND/R-3909-ICTF (Santa Monica, July 1990), p.47.

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The results reported in the prior section included the DMS-10® as a host switch. The DMS-10® has much a much smaller capacity than the DMS-100® or the #5ESS®.[20] Like the larger switches, the DMS-10 can both terminate residential lines and act as a host switch. But the busy-hour capacity of the DMS-10 is much lower than for the other two switches and therefore its getting started cost is less. Since it can process fewer calls, the cost of the central processor that controls these operations is less than for the larger machines.

Since the cost structure of the DMS-10 is different than for the other two host switches, the cost proxy models could be designed to explicitly take into account the lower fixed cost. I do not recommend such a course for two reasons. First, the parameter estimate for the fixed cost of the DMS-10 switch was not statistically significant.[21] Secondly, some of the larger LECs are no longer installing new DMS-10 switch.[22]

Rather, I recommend that proxy models reflect the cost of the DMS-100, #5ESS, their remotes, and EWSD switches. The parameter estimates from these types of switches are reported on the following Table.

```
Regression with robust standard errors                 Number of obs =     2848
                                                       F(  3,  2844) = 2644.93
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.8012
                                                       Root MSE      = 1.1e+06

------------------------------------------------------------------------------
         |             Robust
cost1997 |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 hostexp |   962905.2   80917.07     11.900   0.000       804243.2    1121567
holinexp |   102.5551    3.52579     29.087   0.000        95.6417   109.4684
relinexp |   94.47673   6.513826     14.504   0.000       81.70443    107.249
   _cons |   199412.8   24132.37      8.263   0.000       152094.1   246731.5
------------------------------------------------------------------------------
```

These results can be used as follows within the proxy models:

Investment per host switch = 199,412.8 + 962,905.2 * host_indicator + 102.56* host_lines

[20]David Gabel and Mark Kennet, *Estimating the Cost Structure of the Local Telephone Exchange Network*, NRRI-91-16, p.30.

[21]See file: new log with corrected data.

[22]On the other hand, the DMS-10 continues to be installed by some Independent telephone companies.

= 1,162,318 + 102.56 * host_lines

Investment per remote switch = 199,412.8 + 94.48*remote_lines

As with the prior estimates, the incremental cost of the line must be adjusted upward to reflect utilization. Digital switches do not operate at full capacity. Consequently, where these parameter estimates are used to estimate the cost of providing universal service or unbundled network elements. the values must be divided by the line switch utilization. Line switch utilization typically runs in the range of 90 to 95%.[23]

There is no need to adjust the fixed investment for the switches. The fixed investment is the cost that is incurred as the number of lines asymptotically approaches zero. Since the fixed cost is independent of the level of traffic or the number of lines. it is independent of the level of utilization.

Use of these Parameter Estimates

The Hatfield and Benchmark Cost Proxy Models contain information on the nature of the existing switch nodes. The databases for these models include information on the extent to which each existing switch is either a host or a remote switching machine. Neither Hatfield 3.1 or BCPM 1.0 currently use this data because their current switching cost functions do not distinguish between the cost of a host and remote switch.

Joel Shifman of the Maine Public Utility Commission and I have previously addressed the proposition made by the sponsors of BCPM 1.1. that the fixed cost of a remote and host switching machines are not statistically different:[24]

> The [BCPM] sponsors report that "investigation of the type of switch showed that the host / remote indicator was not statistically significant" and therefore there is no need to distinguish between the cost of a host and remote.[25] This conclusion

[23]There is no need to adjust the fixed investment for the switches. The fixed investment is the cost that is incurred as the number of lines asymptotically approaches zero. Since the fixed cost is independent of the level of traffic or the number of lines, it is independent of the level of utilization.

[24]Maine Public Utilities Commission, "*Ex Parte* Comments Filing Regarding Cost Proxy Models," February 14, 1997, FCC CC Docket No. 96-45, p. 25.

[25] BCPM submission to the FCC, January 30, 1997, Attachment 4, p.38.

> suggests a frightening misunderstanding of statistics and network economics. If there were no difference in the cost of using a host or remote switch, suppliers would not opt to use remote switching machines. Remote switching machines do not provide the same functions as a host. For example, they do not provide connections to toll offices, tandems, or multiple local offices. Neither do remote offices have the same ability to support vertical services or process calls. Because of the limited capabilities of remotes, they cost considerably less than a host-switching machine.

The parameter estimates reported herein provide support for our contention that the getting started cost of a remote and a remote are considerably different. In order to use this information, the code within the models must be changed. In the enclosed disk, we have included a file **.** that describes the code changes that must be made to BCPM in order that this information can be incorporated into the existing models. **See if same coding works with the HM**.

Essentially the algorithm uses the LREG data base to determine if the current switch is a host, stand-alone, or remote switch. If the LREG data base indicates that the switch is a remote, the formula 199,412.8 + 94.48*remote_lines would be employed. If the LREG data base indicates a stand-alone or host switch is present, the formula = 1,162,318 + 102.56 * host_lines would be deployed.

A stand-alone and host machine are similar, but not identical. They both provide multiple direct interoffice routes to other wire centers. The host switch does carry out a function that is not handled by the stand-alone office; the host assists one or more remote switches with the set-up and disconnection of calls. Furthermore, its trunks carry interoffice traffic that is destined for other wire centers.

The umbilical links between the host and remote switching machines are terminated on a digital trunk frame. These frames are quite similar to the frames used for the termination of integrated subscriber line carrier and interoffice trunks. In all three cases, the trunks typically are terminated on the switch at the DS-1 level. The cost of these terminations are not large relative to the total cost of the switch.

Data Issues Regarding the Data Set

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Software costs

When a new switch is installed, the cost of the software is capitalized. Often the cost of the software is added as a loader to the cost of the hardware. Consequently the detailed continuing property records of the local exchange companies typically do not record the explicit cost of the initial software.

The software for the digital switches is updated periodically. When the upgraded software is installed, the cost is expensed, rather than capitalized. Since the initial software is not explicitly recorded on the local exchange companies's detailed continuing property records, the retired software can not be written off the books when the new software load occurs.

Since the cost of the initial software is included in the data set used in this regression, the cost should be excluded from the maintenance factor for the digital switching account. If this exclusion is not made, the cost of the software will be included twice within the study.[26]

Use of Embedded Data

The data set indicates the year in which a digital switch was first installed. Subsequent to the initial installation, equipment may be modified in order to provide new services or functions. For example, in the late 1980s and early 1990s the hardware of both the Nortel and Lucent family of switches were modified due to the technical requirements of the system signaling seven and the CLASS family of products.[27]

I have implicitly assumed that all investments recorded in the data set were made in the year in which the switches were installed. To the extent that this is not true, my treatment of the data results in an understatement of the current cost of the switches. The current cost is understated

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[26]There may be special situations which require the inclusion of some software costs in the maintenance expense factor. As a starting point, I recommend that these expenses be excluded if the regression results reported herein are used in the cost study. For those situations where the cost of the software has been excluded from the investment analysis, it would be appropriate to include the cost of software in the maintenance expense factor.

[27]David Gabel, *Improving Cost Proxy Models for Use in Funding Universal Service*, NRRI 96-34, pp. 50-53.

because I have converted the embedded investment to a current investment by multiplying the embedded investment by the ratio of the telephone plant indexes for the year in which the switch was installed by the 1997 telephone plant index. Since the cost of digital switching has been declining over time, I have effectively deflated the embedded dollars by too large of a ratio. Unfortunately, this problem can not be corrected using publicly available data because the local exchange companies do not report at the sub-account level, digital switching, the additions and retirements made at each switching machine.

The FCC data has also been used by the Bureau of Economic Analysis of the Department of Commerce. Perhaps in recognition of this concern, an analyst with the Bureau of Economic Analysis tested to see if the date that the digital switch was first installed had a statistically significant impact. The BEA analyst included in his hedonic function a variable year, where the value for this explanatory variable was equal to the year the switch was installed. The analyst concluded that the year of installation did not have a statistically significant impact.

I have taken a different approach to this issue. Every three years, Bell Atlantic's depreciation report indicates the book investment of each switch and the number of equipped lines. The BEA data is based on Bell Atlantic's 1995 depreciation study. I also had access to Bell Atlantic's 1992 depreciation report. I put together a data set that included switches that were installed between the 1989 and 1992 depreciation studies. The 1992 and 1995 depreciation report had book investment data for 39 switches that were installed between 1989 and 1991. 1991 was the last year covered by the 1992 report.

In analysis done for the Pennsylvania Office of Consumer Advocate, I tested to see if there was a statistically significant difference in the parameter estimates depending on if data on these 39 switches was obtained from the 1992 or 1995 report. I found that either using a Chow or a dummy variable structural stability test, that there was not a statistically significant difference. The results from this test provide support for using the entire data set.

There is a second influence that can cause costs in the RBOC data set to be overstated. The investment data is drawn from the books of the regional bell operating companies. The data set includes more than just the cost of switching voice calls. For example, the data includes the cost of the main distribution frame and ISDN equipment.. The cost of the main distribution frame is accounted for explicitly in the proxy models and therefore this cost is reflected a second time in the RBOC switching investment data base. Secondly, since the cost of ISDN and other non-POTS switching investments are included in the data set, costs are included that are not associated with providing basic telephone service.

It is not possible to tell *a priori* which of the two effects discussed in this section, over deflating book investments or excluding non-switch related costs, dominate. Fortunately though, the estimates from the RUS data are not contaminated in this fashion and therefore provide a validity check on the parameter estimates provided in this chapter.

Comparison of Econometric Estimates with Other Studies

I have used publicly available data to obtain the estimates reported in this chapter. In a typical rate proceeding, a large local exchange company relies on an engineering process model, such as the Switching Cost Information System (SCIS), to estimate its switching investments. It is not possible in this monograph to compare these parameter estimates with the SCIS values because of the restraints imposed by Bellcore. Bellcore prohibits public disclosure of the SCIS estimates and the methods used to obtain those estimates.

Estimates of the cost of new switching equipment can be made from public reports of the RBOCs, but the data is not very useful. For example, it is possible to identify the yearly incremental investment in digital switching and the number of additional working lines on the digital switches. The quotient of these two values provides a poor estimate of the average investment per line. It is not possible to tell the extent the which the values used in such a calculation are associated with adding capacity to existing switches, versus the installation of new switching machines. Furthermore, the year in which certain expenses are capitalized can differ from the year in which the additional lines are reported.

Estimating the Cost of Switching and Cables Based on Publicly Available Data--NRRI work in progress--August 19, 1997

Methodology Used in Analyzing the Rural Utilities Services Outside Plant Data

For a flow chart outlining the various steps discussed below, refer to Appendix B.

ASSIGNMENT OF PLACEMENT DIFFICULTY

Using MS ACCESS, the following information for each RUS company was pulled from the Hatfield data base and placed into an Excel workbook;

1. CLLI code
2. CBG designation
3. Area (sq. Mile)
4. Fraction Empty
5. Total Lines
6. Density Lines/Sq. Mile
7. Rock Depth
8. Rock Hardness
9. Surface Texture
10. Water Depth
11. Populated Area (sq. Mile)

The eleventh designation, Populated Area (sq. Mile), was calculated by using the formula, Area (sq. Mile) * (1- Fraction Empty) = Populated Area (sq. Mile).

In the Excel workbook this data was then used to calculate the values for the following designations based on the methodology used by the BCPM model;

12. Surface Indicator
13. Copper Depth Condition
14. Fiber Depth Condition
15. Copper Placement Difficulty Level
16. Fiber Placement Difficulty Level

The copper and fiber placement difficulty levels, Nos. 15 and 16 above, are characterized, in increasing placement levels of placement difficulty, as follows;

1. (Normal) Neither water table depth nor depth to bedrock is within placement depth for copper or fiber cable and surface soil texture does not interfere with plowing.
2. Either soft bedrock is within cable placement depth or surface soil texture interferes with plowing.
3. Hard bedrock is within cable placement depth.